

## CLAIMS

- 1           1.       A multi-stage optical amplifier, comprising:  
2           an optical fiber including a first length of amplifier fiber and a  
3       second length of amplifier fiber, the optical fiber configured to be coupled  
4       to a signal source that produces at least a signal wavelength  $\lambda_s$  and a pump  
5       source that produces a pump wavelength  $\lambda_p$ , wherein pump wavelength  $\lambda_p$   
6       is less than signal wavelength  $\lambda_s$ ;  
7           a signal input port coupled to the optical fiber;  
8           a signal output port coupled to the optical fiber;  
9           a pump input port coupled to the optical fiber;  
10          a first lossy member coupled to the optical fiber and positioned  
11       between the first and second lengths of amplifier fiber, the first lossy  
12       member being lossy in at least one direction; and  
13          a pump shunt coupled to the signal input port and the signal output  
14       port.  
1           2.       The multi-stage optical amplifier of claim 1, wherein the  
2       first and lengths of amplifier fiber each have a length greater than or equal  
3       to 200m.  
1           3.       The multi-stage optical amplifier of claim 1, wherein pump  
2       radiation of wavelength  $\lambda_p$  is in the range of 1300 nm to 1530 nm  
1           4.       The multi-stage optical amplifier of claim 1, wherein signal  
2       radiation of wavelength  $\lambda_s$  is in the range of 1430 to 1530 nm.  
1           5.       The multi-stage optical amplifier of claim 1, wherein the  
2       first lossy member is an optical isolator.  
1           6.       The multi-stage optical amplifier of claim 1, wherein the  
2       first lossy member is an add/drop multiplexer.  
1           7.       The multi-stage optical amplifier of claim 1, wherein the  
2       first lossy member is a gain equalization member.

1           8.     The multi-stage optical amplifier of claim 1, wherein the  
2 first lossy member is a dispersion compensation element.

1           9.     The multi-stage optical amplifier of claim 1, wherein the  
2 first length of amplifier fiber is a Raman amplifier.

1           10.    The multi-stage optical amplifier of claim 1, wherein the  
2 second length of amplifier fiber is a Raman amplifier.

1           11.    The multi-stage optical amplifier of claim 1, wherein at  
2 least one of the first and second Raman fiber amplifiers is a dispersion  
3 compensating fiber.

1           12.    The multi-stage optical amplifier of claim 11, wherein the  
2 first and Raman fiber amplifiers are each dispersion compensating fibers.

1           13.    The multi-stage optical amplifier of claim 1, wherein the  
2 first length of amplifier fiber has lower noise than the second length of  
3 amplifier fiber.

1           14.    The multi-stage optical amplifier of claim 1, wherein the  
2 second length of amplifier fiber has a higher gain than the first length of  
3 amplifier fiber.

1           15.    The multi-stage optical amplifier of claim 1, further  
2 comprising:

3           at least one WDM coupler to couple a pump path from the signal  
4 input port to the signal output port.

1           16.    The multi-stage optical amplifier of claim 1, wherein the  
2 first length of amplifier fiber has an optical noise figure of less than 8 dB.

1           17.    The multi-stage optical amplifier of claim 1, wherein the  
2 second length of amplifier fiber has a gain level of at least 5 dB.

1           18.    The multi-stage optical amplifier of claim 1, further  
2 comprising:

3           a pump source coupled to the pump input port.

4           19.    The multi-stage optical amplifier of claim 1, further  
5 comprising:

6           at least one laser diode pump source coupled to the pump input  
7 port.

1           20.    The multi-stage optical amplifier of claim 1, further  
2 comprising:

3           a second lossy member coupled to the pump shunt.

4           21.    The multi-stage optical amplifier of claim 1, wherein the  
5 pump shunt includes an optical fiber.

1           22.    A broadband booster amplifier, comprising:

2           a plurality of transmitters transmitting a plurality of wavelengths;

3           a combiner coupled to the plurality of transmitters;

4           an optical fiber coupled to the combiner, the optical fiber including  
5 a first length of amplifier fiber and a second length of amplifier fiber, the  
6 optical fiber configured to be coupled to a signal source and a pump  
7 source;

8           a signal input port coupled to the optical fiber;

9           a signal output port coupled to the optical fiber;

10          a pump input port coupled to the optical fiber;

11          a first lossy member coupled to the optical fiber and positioned  
12 between the first and second lengths of amplifier fiber, the first lossy  
13 member being lossy in at least one direction; and

14          a pump shunt coupled to the signal input port and the signal output  
15 port.

1           23.     A broadband pre-amplifier, comprising:  
2           an optical fiber including a first length of amplifier fiber and a  
3           second length of amplifier fiber, the optical fiber configured to be coupled  
4           to a signal source and a pump source;  
5           a signal input port coupled to the optical fiber;  
6           a signal output port coupled to the optical fiber;  
7           a pump input port coupled to the optical fiber;  
8           a first lossy member coupled to the optical fiber and positioned  
9           between the first and second lengths of amplifier fiber, the first lossy  
10          member being lossy in at least one direction;  
11          a pump shunt coupled to the signal input port and the signal output  
12          port;  
13          a splitter coupled to the signal output port; and  
14          a plurality of receivers coupled to the splitter.

1           24.     A broadband communication system, comprising:  
2           a transmitter;  
3           an optical fiber including a first length of amplifier fiber and a  
4           second length of amplifier fiber, the optical fiber configured to be coupled  
5           to a signal source and a pump source;  
6           a signal input port coupled to the optical fiber;  
7           a signal output port coupled to the optical fiber;  
8           a pump input port coupled to the optical fiber;  
9           a first lossy member coupled to the optical fiber and positioned  
10          between the first and second lengths of amplifier fiber, the first lossy  
11          member being lossy in at least one direction;  
12          a pump shunt coupled to the signal input port and the signal output  
13          port; and  
14          a receiver coupled to the optical fiber.

15           25.    The system of claim 24, wherein the first and lengths of  
16 amplifier fiber each have a length greater than or equal to 200m.

1           26.    The system of claim 24, further comprising:  
2           a pump source producing radiation of wavelength  $\lambda_p$  in the range of  
3 1300 nm to 1530 nm

1           27.    The system of claim 24, further comprising:  
2           a signal source producing radiation of wavelength  $\lambda_s$  in the range of  
3 1430 to 1530 nm.

1           28.    The system of claim 24, wherein the first lossy member is  
2 an optical isolator.

1           29.    The system of claim 24, wherein the first lossy member is  
2 an add/drop multiplexer.

1           30.    The system of claim 24, wherein the first lossy member is a  
2 gain equalization member.

3           31.    The system of claim 24, wherein the first lossy member is a  
4 dispersion compensation element.

1           32.    The system of claim 24, wherein the first length of  
2 amplifier fiber is a Raman amplifier.

1           33.    The system of claim 24, wherein the second length of  
2 amplifier fiber is a Raman amplifier.

1           34.    The system of claim 24, wherein at least one of the first and  
2 second Raman fiber amplifiers is a dispersion compensating fiber.

1           35.    The system of claim 34, wherein the first and Raman fiber  
2 amplifiers are each dispersion compensating fibers.

1           36.    The system of claim 24, wherein the first length of  
2 amplifier fiber has lower noise than the second length of amplifier fiber.

1           37.    The system of claim 24, wherein the second length of  
2 amplifier fiber has a higher gain than the first length of amplifier fiber.

1           38.     The system of claim 24, further comprising:  
2           at least one WDM coupler to couple a pump path from the signal  
3 input port to the signal output port.

1           39.     The system of claim 24, wherein the first length of  
2 amplifier fiber has an optical noise figure of less than 8 dB.

1           40.     The system of claim 24, wherein the second length of  
2 amplifier fiber has a gain level of at least 5 dB.

1           41.     The system of claim 24, further comprising:  
2 a laser diode pump source coupled to the pump input port.

1           42.     The system of claim 24, further comprising:  
2 a second lossy member coupled to the pump shunt.

1           43.     The system of claim 24, wherein the pump shunt includes  
2 an optical fiber.

1           44.     A broadband communication system, comprising:  
2 a transmitter;  
3 an optical fiber coupled to the transmitter, the optical fiber  
4 including a first length of amplifier fiber and a second length of amplifier  
5 fiber, the optical fiber configured to be coupled to a signal source and a  
6 pump source;

7           a signal input port coupled to the optical fiber;

8           a signal output port coupled to the optical fiber;

9           a pump input port coupled to the optical fiber;

10          a first lossy member coupled to the optical fiber and positioned  
11 between the first and second lengths of amplifier fiber, the first lossy  
12 member being lossy in at least one direction;

13          a pump shunt coupled to the signal input port and the signal output  
14 port;

15          at least one in-line broadband amplifier coupled to the optical fiber;

16 and

17 a receiver coupled to the in-line broadband amplifier.

1 45. The system of claim 44, wherein the in-line broadband  
2 amplifier comprises:

3 an optical fiber including a first length of amplifier fiber and a  
4 second length of amplifier fiber, the optical fiber configured to be coupled  
5 to a signal source and a pump source;

6 a signal input port coupled to the optical fiber;

7 a signal output port coupled to the optical fiber;

8 a pump input port coupled to the optical fiber;

9 a first lossy member coupled to the optical fiber and positioned  
10 between the first and second lengths of amplifier fiber, the first lossy  
11 member being lossy in at least one direction; and

12 a pump shunt coupled to the signal input port and the signal output  
13 port.

1 46. A broadband communication system, comprising:

2 a transmitter;

3 a broadband booster amplifier;

4 an optical fiber coupled to the broadband booster amplifier, the  
5 optical fiber including a first length of amplifier fiber and a second length  
6 of amplifier fiber, the optical fiber configured to be coupled to a signal  
7 source and a pump source;

8 a signal input port coupled to the optical fiber;

9 a signal output port coupled to the optical fiber;

10 a pump input port coupled to the optical fiber;

11 a first lossy member coupled to the optical fiber and positioned  
12 between the first and second lengths of amplifier fiber, the first lossy  
13 member being lossy in at least one direction;

14 a pump shunt coupled to the signal input port and the signal output  
15 port;  
16 and  
17 a receiver coupled to the optical fiber.

1 47. The system of claim 46, wherein the broadband booster  
2 amplifier comprises:

3 a plurality of transmitters transmitting a plurality of wavelengths;  
4 a combiner coupled to the plurality of transmitters;  
5 an optical fiber coupled to the combiner, the optical fiber including  
6 a first length of amplifier fiber and a second length of amplifier fiber, the  
7 optical fiber configured to be coupled to a signal source and a pump  
8 source;

9 a signal input port coupled to the optical fiber;  
10 a signal output port coupled to the optical fiber;  
11 a pump input port coupled to the optical fiber;  
12 a first lossy member coupled to the optical fiber and positioned  
13 between the first and second lengths of amplifier fiber, the first lossy  
14 member being lossy in at least one direction; and  
15 a pump shunt coupled to the signal input port and the signal output  
16 port.

1 48. A broadband communication system, comprising:  
2 a transmitter;  
3 an optical fiber coupled to the transmitter, the optical fiber  
4 including a first length of amplifier fiber and a second length of amplifier  
5 fiber, the optical fiber configured to be coupled to a signal source and a  
6 pump source;  
7 a signal input port coupled to the optical fiber;  
8 a signal output port coupled to the optical fiber;



9 a pump input port coupled to the optical fiber;  
10 a first lossy member coupled to the optical fiber and positioned  
11 between the first and second lengths of amplifier fiber, the first lossy  
12 member being lossy in at least one direction;  
13 a pump shunt coupled to the signal input port and the signal output  
14 port;  
15 a broadband pre-amplifier coupled to the optical fiber; and  
16 a receiver coupled to the broadband pre-amplifier.

1 49. The system of claim 48, wherein the broadband pre-  
2 amplifier comprises:

3 an optical fiber including a first length of amplifier fiber and a  
4 second length of amplifier fiber, the optical fiber configured to be coupled  
5 to a signal source and a pump source;  
6 a signal input port coupled to the optical fiber;  
7 a signal output port coupled to the optical fiber;  
8 a pump input port coupled to the optical fiber;  
9 a first lossy member coupled to the optical fiber and positioned  
10 between the first and second lengths of amplifier fiber, the first lossy  
11 member being lossy in at least one direction;  
12 a pump shunt coupled to the signal input port and the signal output  
13 port;  
14 a splitter coupled to the signal output port; and  
15 a plurality of receivers coupled to the splitter.

1 50. A broadband communication system, comprising:  
2 a transmitter;  
3 a broadband booster amplifier coupled to the transmitter;  
4 an optical fiber coupled to the booster broadband amplifier, the  
5 optical fiber including a first length of amplifier fiber and a second length

6 of amplifier fiber, the optical fiber configured to be coupled to a signal  
7 source and a pump source;  
8 a signal input port coupled to the optical fiber;  
9 a signal output port coupled to the optical fiber;  
10 a pump input port coupled to the optical fiber;  
11 a first lossy member coupled to the optical fiber and positioned  
12 between the first and second lengths of amplifier fiber, the first lossy  
13 member being lossy in at least one direction;  
14 a pump shunt coupled to the signal input port and the signal output  
15 port;  
16 a broadband pre-amplifier coupled to the optical fiber; and  
17 a receiver coupled to the broadband pre-amplifier.

1 51. The system of claim 50, wherein the broadband booster  
2 amplifier comprises:

3 a plurality of transmitters transmitting a plurality of wavelengths;  
4 a combiner coupled to the plurality of transmitters;  
5 an optical fiber coupled to the combiner, the optical fiber including  
6 a first length of amplifier fiber and a second length of amplifier fiber, the  
7 optical fiber configured to be coupled to a signal source and a pump  
8 source;  
9 a signal input port coupled to the optical fiber;  
10 a signal output port coupled to the optical fiber;  
11 a pump input port coupled to the optical fiber;  
12 a first lossy member coupled to the optical fiber and positioned  
13 between the first and second lengths of amplifier fiber, the first lossy  
14 member being lossy in at least one direction; and  
15 a pump shunt coupled to the signal input port and the signal output  
16 port.

1           52.     The system of claim 51, wherein the broadband pre-  
2 amplifier comprises:  
3           an optical fiber including a first length of amplifier fiber and a  
4 second length of amplifier fiber, the optical fiber configured to be coupled  
5 to a signal source and a pump source;  
6           a signal input port coupled to the optical fiber;  
7           a signal output port coupled to the optical fiber;  
8           a pump input port coupled to the optical fiber;  
9           a first lossy member coupled to the optical fiber and positioned  
10 between the first and second lengths of amplifier fiber, the first lossy  
11 member being lossy in at least one direction;  
12           a pump shunt coupled to the signal input port and the signal output  
13 port;  
14           a splitter coupled to the signal output port; and  
15           a plurality of receivers coupled to the splitter.